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PROTECT FROZEN FOODS from TEMPERATURE DAMAGE

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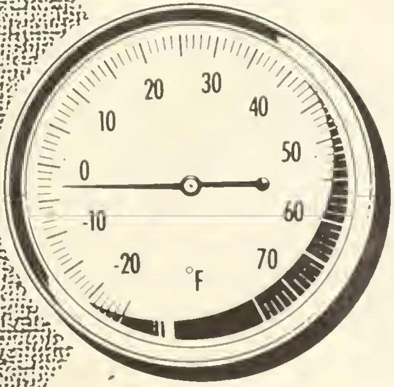

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Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

The Time-Temperature-Tolerance Project

When the temperature of a frozen food reaches 10° F., 20° F., or higher, and when several hours, a day, or a month passes before it again reaches 0° F. or lower, what happens to the original flavor, color, texture, vitamin content?

What happens if it meets several of these temperature hazards - - say five, ten, or more - - between producer and consumer?

This report supplies facts in answer to these questions. The facts are a result of a project, proposed and aided by the frozen-food industries, that has related processing procedures used in manufacture.to the stability of these products during subsequent handling. The project is well along in the Western Utilization Research and Development Division of the Agricultural Research Service, U. S. Department of Agriculture.

Other results are better tests for losses of high quality and better knowledge of what each industry - - from packer to retailer - - can do to protect it.

This report summarizes results obtained - - presented in relation to the problems of temperature control in commercial operations. Technical reports are available to those who request them.

Prepared originally in September, 1957. Revised in February, 1958. For additional information, write Western Regional Research Laboratory, headquarters of the Western Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture, Albany 10, California.

PROTECT FROZEN FOODS FROM TEMPERATURE DAMAGE

THE HIGH-QUALITY CONCEPT for frozen foods differs from that for other processed foods in important respects. With frozen foods the aim is to preserve fresh or freshly prepared quality in its prime state. As much as possible heating, if required at all, is applied after the foods reach the consumer.

Temperature thus predominates. At room temperature, fresh foods keep for short periods. If prepared for serving or cooking—peeled, cut up, or otherwise prepared, as they are for freezing—quality declines much faster. The home refrigerator retards losses. Freezing in good packages and holding consistently at 0° F. and lower protect high quality for year-round operations.

A major aim of the Time-Temperature-Tolerance Project was to gain facts on changes in quality during transport, storage, and wholesale and retail selling of frozen foods, which could be translated into improved techniques for better protection. Thousands of samples were collected from major producing areas over a period of years. In the research, chemical methods were used to measure vitamins and other compounds. Instruments were used to measure color and texture. Human tasters were used to measure flavor and appearance. These methods supplied reliable information.

Several useful and important general statements based on the research are as follows:

The chemical actions that result in quality loss accelerate as temperature rises from 0° F. or lower level. At 15° changes occur several times as fast as at 0°, and at 25° several times as fast as at 15° F. But many products feel hard at 20° F. It is therefore erroneous to assume that a cold and hard package is adequately protected.

Casual inspection is not a safe way to estimate quality. Initial stages of loss are not visually detectable. Frozen food that looks good may be well along toward serious loss.

An important fact is that temperature damage is retained indefinitely. Return to zero and lower does not correct it. As temperature rises or falls, losses move faster or slower. They never move in reverse.

Kinds and Rates of Quality Loss at Various Temperatures

FROZEN FRUITS Frozen fruits are damaged in several ways, and certain kinds of damage become conspicuous early. Changes in color and appearance are easily detected. Less easily detected changes occur at the same time.

Examples are dark-brown peach slices, discolored strawberries, raspberries with color bled into the sirup, dull-brown cherries with toughened skins.

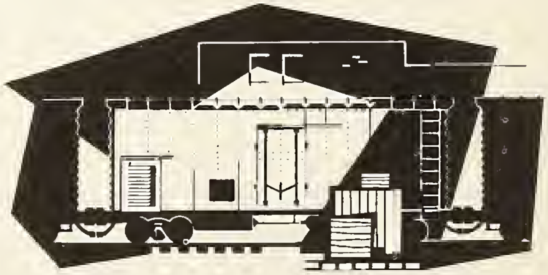
Of four fruits investigated, frozen peaches reveal damage most quickly. Brown slices often become apparent after total exposures of 1 to 2 days or less time at 30°, 2 weeks at 20°, 2 to 3 months at 10° or more than a year at 0° F. and lower temperature.

Strawberries undergo flavor changes that become easily detectable within totals of 1 to 2 days at 30°, 6 to 12 days at 20°, or about 3 months at 10° F.—but lose little quality in well over a year at 0° F. and lower. Discoloration and loss of vitamin C (ascorbic acid) develop at the same time. Flavor loss develops early.

Frozen raspberries reveal temperature damage less quickly than other fruits but lose color from berries to sirup at fairly rapid rates. This change is not accompanied by drastic change in flavor but it indicates a loss of fresh condition. Zero and lower temperatures supply protection.

Fruits contain important amounts of vitamin C. Top-quality strawberries are especially rich in this vitamin. Frozen peaches are commonly packed with added ascorbic acid to retard browning. Temperature abuse causes losses of this vitamin and the rate is related to rates of other losses.

Those who handle frozen fruits, and also other products, may well remember this fact: Held a day at 20° F., they may not show damage—for example, peaches may not turn brown. The next handler, however, may expose the product to minor temperature hazards and find that the damage is conspicuous, and it can't be corrected.



FROZEN CONCENTRATED ORANGE JUICE This product is a major outlet for a large crop and a major frozen food. It is widely consumed for its vitamin C and other nutritive values. Its color, flavor, and stability of its cloud are quality factors to which consumers are highly sensitive.

The metal containers protect against air and thus limit oxidative reactions, but they allow undetected thawing of the product that would damage most other containers. Though we may assume that the juice is being protected, actually it is undergoing changes that may cause consumers to regard it as a low-grade rather than a high-grade product.

Tendency to "lose cloud" (that is, to separate when mixed with water) has led to an industry-wide practice of mild heating in the processing of this concentrate. This practice has improved stability but temperature damage remains a major problem. In the research, cloud loss was observed in all samples but in varying degrees above 0° F. Over long periods at 0° F., the juice gradually loses ability to withstand temperature damage.

In the research some, but not all, heat-treated samples retained stable cloud during 5 days at 10° followed by a steady rise to 40° with immediate refreezing to 0°F. All unheated samples failed in this test. All those heat-treated that survived the first test failed in a second test later.

In the lower range of exposures for longer times, most unheated samples retained cloud when exposures over a year added up to no more than 24 days at 10° F. Heated samples generally withstood treatment twice as severe, but varied. Thus temperature damage accumulates and quickly exhausts the original stability of this important product.

Undesirable change in flavor was found to be slower than cloud loss, and loss of vitamin C much slower. These losses, however, do proceed faster as temperature rises and eventually add severely to total quality losses in frozen concentrated orange juice. Unfavorable time-temperature experiences that may not cause undesirable flavor change always increase the probability of change after subsequent temperature abuse.

FROZEN VEGETABLES Temperature-tolerance studies on vegetables have supplied general descriptions of quality losses and measurements of rates. Temperature-damaged green snap beans, for example, first darken and later turn olive drab and eventually brown. Peas turn grayish-green and then yellowish as green color is lost.

Trained judging panels are consistently able to detect a color change in beans held at 0° F. for about 4 mnoths. They can do the same with peas at 0° F. after about 6 months. These observations indicate the comparative rates of color change in these two products. They do not evaluate the severity of damage; at zero steadily held, overall quality continues at a high level for at least one year.

The trained panel identifies the same change mentioned above in beans held at 10° after one month, after 10 days at 20°, and after about 3 days at 30° F. For peas the time periods are roughly double in each case.

Undesirable change in flavor of beans is detectable by the trained panel after 3 to 4 times the periods required for detections of color change at the various temperatures listed above. Flavor change in peas is slightly more rapid. Thus for both vegetables, color changes more rapidly than flavor.

Losses of chlorophyll (green pigment) and vitamin C are useful measures of loss of quality. In effectively blanched green beans, chlorophyll is lost at the rate of about 10% per year at 0° F., which is not severe. At 10°, however, this rate triples. At 20° it is 16 times and at 30° F. 60 times as fast as at 0° F. Improperly blanched beans will lose color even faster. Rates of loss of vitamin C vary similarly with temperature.

The facts above emphasize the striking increases in rates as temperatures rise higher and higher above zero—and particularly as they reach temperature levels of 25°, 30°, and above. Long periods at lower temperature above 0°F.—without apparent thawing or softening—will result in the same sort of damage. Thus the following times and temperatures are approximately equivalent: 1 year at 0°, 6 months at 5°, 3 months at 10°, 6 weeks at 15°, 3 weeks at 20°, 10 days at 25°, and 5 days at 30°F.

FROZEN POULTRY PRODUCTS Quality losses in frozen ready-to-cook poultry arise from moisture loss, rancidification, and darkening. Rate of deterioration approximately doubles for each 10 degrees rise in temperature. Turkeys are less stable than chickens, and cut-up poultry is less stable than whole birds.

Lowering temperature lessens moisture loss, which causes unattractive appearance. Poorly packaged cut-up chicken fryers lost 1.1% moisture in 4 months at 10° F., but only 0.2% at -10° F. This loss is reduced also by moisture-proof packaging. Package failure arises from rough handling, poor material, or failure to seal effectively.

Rancidity is also reduced by lowering temperature and use of less permeable packaging materials. Products that develop rancid off-flavor within 1 month at 20° are stable for 3 months at 10°, 6 months at 0°, and 10 months at -10° F.

Two other temperature-sensitive changes are frost formation in the package and darkening of skin. Frosting can occur in a moisture-proof package and is increased by widely fluctuating temperatures. Darkening takes place when frozen turkeys are allowed to stand for excessively long periods at 10° to 25° F. in distribution and retailing. Low steady temperature (0° F.) will minimize or prevent both of these changes.

For average commercial frozen poultry products in relatively moisture- and airproof packages, 0° F. maintains optimum quality for a year and provides a margin of safety for most distribution schedules.

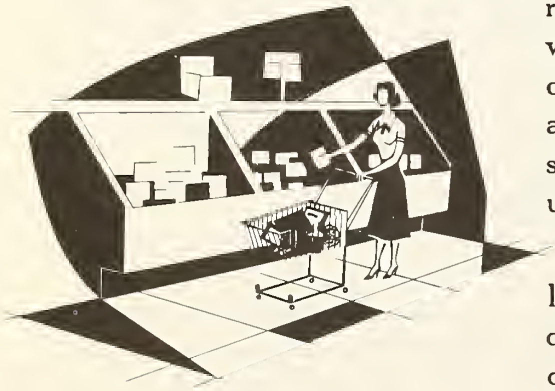
PREPARED FROZEN FOODS Products studied thus far are fried chicken, turkey dinners and pies, creamed chicken and turkey products, and sauces and gravies used in such products as a la king and custard and pudding desserts.

The flavor change first detected in cooked poultry meat is loss of "freshly cooked" flavor, which is followed eventually by staleness and finally by distinct rancidity. At 20° F. flavor changes are detectable in fried chicken within less than 2 weeks, staleness or rancidity develops within 6 weeks to 3 months, and mold occurs on pies held 9 months. At 10°F. and lower, stability of flavor is greatly affected by exposure of the meat to air. For example, the sauce or gravy in pies protects the meat, and hence dinners, pies, creamed products and a la king are protected against serious flavor damage for as long as 6 to 12 months at 10° F. or lower. Fried chicken, however, suffers damage in half that time at these temperatures.

Curdling, separation of liquid, and loss of smoothness are undesirable changes that can develop in puddings, desserts and gravies after they are thawed. Such foods become much more defective in this respect when exposed to temperatures above 0° F. Research has revealed improvement from use of certain thickening agents (such as waxy rice flour) and stabilizers, but even improved products are more stable at 0° F. than at higher temperatures.

Effects of Specific Exposures to Temperatures Above Zero

The Time-Temperature-Tolerance Project has provided, for those who handle frozen foods, a clearer understanding of the effects on high quality of single and repeated exposures above zero. Excessive exposures on docks, during transport or delivery, in retail stores and elsewhere always include a series of temperatures.



An experience of rising and falling temperature always involves more time at lower levels, where rates of change are slower, than at higher levels, where rates are increasingly faster. An accurate concept of the effects of experiences above zero always involves curves or patterns, such as those shown in the chart on the following page (Figure 1).

In this chart the vertical temperature scales are drawn so that they represent the increasing rate of loss of vitamin C in frozen strawberries as temperature rises. The distance between the straight horizontal lines drawn from 20° and 25° is roughly twice the distance between those from 15° and 20° F. That is, rate of loss of vitamin C approximately doubles with each 5 degrees of increase in temperature. At 25° to 30° F. it is very fast indeed.

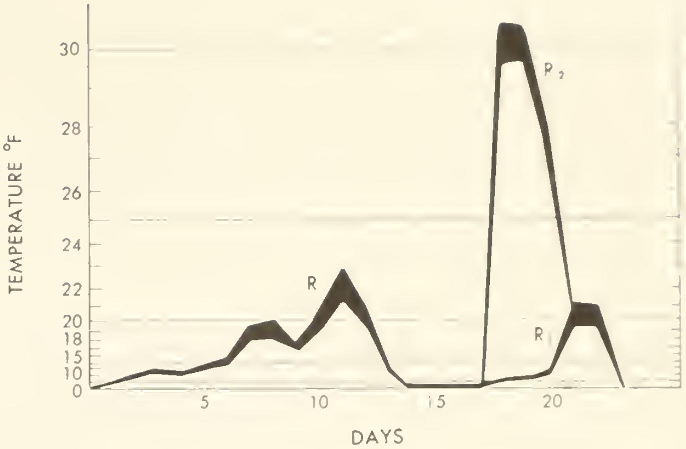


FIGURE 1

When the temperature record of a shipment is plotted on this chart, the area beneath the curve is actually proportional to the amount of loss of vitamin C. In this plot the segment indicated by R, about 17 days, represents temperatures from an actual shipment of commercial frozen foods. R_1 and R_2 represent subsequent periods of a few days in which temperature rises to 20° and to 30° F., respectively. This chart has been taken from a technical report, based on studies of samples exposed in rooms supplied with controlled variable temperature. The blackened curve area represents the variation between maximum and minimum rates for 95% of the lots tested.

The important fact illustrated is that the rise to 30° causes much more damage than rises to lower levels. The areas beneath curves R, R_1, and R_2 supply true and useful concepts of the effects of exposures on high quality.

The research also included measurement of changes in vitamin C and color in raspberries, peaches, and strawberries in temperature experiences of R, $R + R_1$, and $R + R_2$ These losses were definitely proportional to the spaces encompassed by the curves. For example strawberries lost 21.1 weight units of vitamin C in $R + R_2$. In $R + R_1$ they lost 9.0 units. In R alone they lost 6.9. Good fresh strawberries contain 40 to 50 such units, which are measured in thousandths of an ounce or gram per 100 ounces or grams (or other weight units) of berries.

This concept is useful and valid in a general way for the kinds of high-quality losses in various frozen foods mentioned in the previous section of this report. Important matters are the rapid increase in rate and extent of damage as temperature rises and the fact that early and slight damage is important because it accumulates. The damage in R_1 and R_2 is added to that of R.

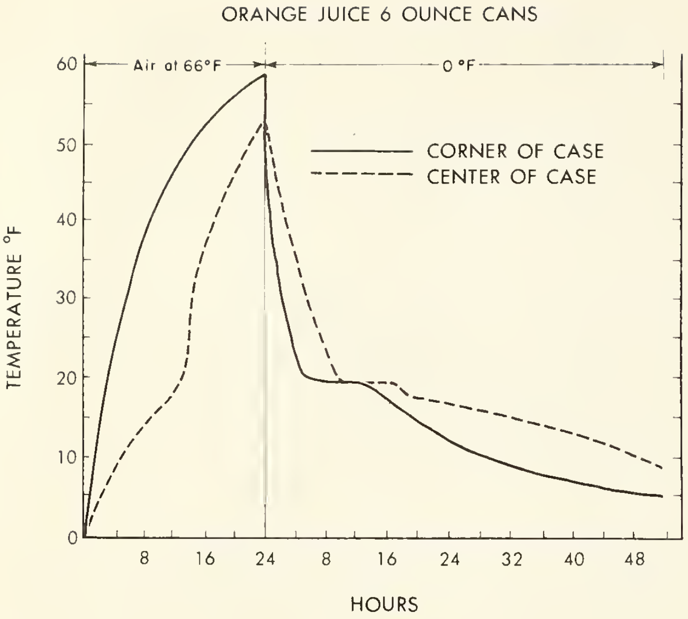


FIGURE 2

The temperatures and times shown in Figure 2 also contribute to practical understanding of effects of exposures of frozen foods to temperatures above zero. It is one of numerous charts of data obtained in the Time-Temperature-Tolerance Project.

A case of frozen orange concentrate was placed in a room at 66° F. Temperatures in the corner and in the center of the case were measured. Within 4 hours the temperature in the corner was 25° and in the center it was less than 10° F. After 8 hours these were 35° and 15° F.

After 24 hours the case was returned to a room at 0° F. with moderate air movement. An important fact is the long period required to reach 0° F. The full time extends well beyond the 2 days represented in the chart.

In contrast to Figure 1, this chart does not show the extent of increased damage at the higher levels. It does show some useful facts about temperature changes.

Measuring Temperatures

Improved handling requires constant attention to product temperatures. Control of product temperatures in turn means measurements taken consistently, in the products themselves and in their environments. Frequent temperature measurement enables one to become "temperature minded" and to understand equipment performance as well as quality losses.

As an aid to greater and more effective use of thermometers, the Time-Temperature-Tolerance Project included a study of product temperature measurement in cases of frozen foods without destruction of individual packages. The method simplifies the operation, reduces time required, and produces accurate results.

A metal, disk-type thermometer is used. A carton is opened. Then two packages in the corner are removed. With an ice pick or similar tool a hole is punched from the inside, so that the thermometer stem can be inserted, from the outside, exactly between tiers of packages. The thermometer stem is inserted. The two packages are returned to their places. The carton is closed. Other cartons are placed on top to cause the packages to press firmly on the stem. After 5 minutes the temperature is read.

Another method is as follows: With a razor knife a small opening is made in the carton wall to reveal where the corner package comes together with the next one. The thermometer stem is simply inserted about 3 inches in contact with both packages. The cut end of the carton opening is forced against the stem. About 5 minutes are required to obtain a reading that closely approximates that of the center of the product.

Thermometer readings are important. They measure not only degree of protection but also rates at which quality is disappearing.

Other Phases of the Project

This report discusses phases of the Time-Temperature-Tolerance research that contribute to a practical and reliable concept of the effects of exposures of frozen foods to temperatures above zero. This concept includes the numerous kinds and rates of damage, the acceleration of rates as temperature rises, and the fact that mild early damage is serious because it acumulates during repeated or continued exposures.

The project results also suggest the use of certain objective tests. The test for vitamin C can be carried out by anyone with sufficient laboratory experience. The original content of ascorbic acid in strawberries can be determined by measurement of its breakdown products. The test for chlorophyll (green pigment) and its conversion to pheophytin is useful. Measuring the extent to which red color of raspberries has moved into the sirup is an indicator of temperature experience. If sugar concentration in berries is the same as in the sirup, previous thawing is indicated.

The technical results, which are reported in an extensive series of articles, contain information on processing as related to stability of the frozen foods during subsequent handling and other problems. These reports are available on request.